Best Management Practices for the Manufacture of Electronics with Lead Solder

Commonwealth of Massachusetts
Executive Office of Environmental Affairs
Office of Technical Assistance and Technology

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Introduction

Changes in state and federal reporting requirements have increased the importance of lead use reduction by manufacturers in Massachusetts, particularly those in the electronics industry. In 1999, EPA classified lead and lead compounds as Persistent, Bioaccumulative, and Toxic (PBT) chemicals. PBT chemicals are a concern because they are highly toxic, do not break down easily in the environment, and accumulate in living tissues. **Because of these three characteristics, the TRI/TURA reporting thresholds for lead have been reduced from 25,000 pounds per year processed to only 100 pounds per year which means that if your facility uses 270 pounds or more of 63Sn/37Pb solder per year, you trip the threshold.** This change is part of a nationwide initiative to reduce the risks to human health and the environment from exposure to PBT pollutants.

Waste electronics has become the fastest growing class of waste in the United States. Both the US EPA and Commonwealth of Massachusetts have expressed concern over releases of heavy metals, flame retardants and plasticizers to the air from waste incinerators or to groundwater from landfill leachate. This concern prompted them to impose restrictions, fees, and recycling directives on lead users. Prudent manufacturers of electronic products should minimize waste from the manufacturing process, reevaluate waste recycling or disposal, and design products with less toxic material.

I. Printed Wiring Board Assembly and Soldering

In the electronics manufacturing industry there are several types of soldering available to facilities. They include, Wave Soldering, Reflow (Paste) Soldering, and Hand Soldering. Each is applied for different purposes with opportunities for waste reduction.

A. Wave Soldering

Wave soldering is a common mass soldering technique. In Massachusetts more lead use and byproducts are attributed to wave soldering than to any other form of soldering. In wave soldering, the greatest opportunity to reduce solder waste is through dross reduction, although this may also be accomplished through recovery and recycling.

Above: Examples of 3 different types of Wave Soldering Machines
(Photo courtesy of Novastar Wave Soldering)

1. Dross Reduction

Dross tends to form and remain on the top surface of the molten solder as a result of oxidation or reaction with sulfides, fluxes, or other contaminants. Dross will adversely affect the quality of solder joints and is often removed as a waste material for recycling or disposal. There are several ways to minimize dross, which will both improve the quality of the finished product and reduce the amount of waste generated. They are:

- Minimize solder impurities: Other metals, such as zinc, aluminum and cadmium (and higher concentrations of copper and iron) can lead to a significant increase in the dross. If the dross on a wave machine unexpectedly increases beyond the amount required by the equipment specifications, you should check the analysis of the solderbath. Use low-solids, no-clean flux when possible.
- Analyze the solder pot: Don't replace the entire contents of the solder pot based entirely upon a calendar schedule. Make adjustments, perhaps on an activity based frequency to maintain the composition within acceptable parameters for consistent product. Decanting a smaller volume of solder and replacing it with virgin material should reduce annual solder use.
- Minimize turbulence: Turbulence occurs in the manufacturing process when solder falls into the solder reservoir. Dross is then dragged, with air, through the surface of the solder. The result is the formation of a thick layer of drossy sludge on the bath surface. Falling solder may be intercepted on most soldering machines by baffles and catchment devices that return it to the solderbath with reduced turbulence.
- Use floating round glass beads: The beads, when rotated slowly by the falling solder in the waterfall zone, mechanically breaks up the wet dross.
- Keep solder pot temperature below 500°F: Drossing increases quickly when operating temperatures are above this temperature. However, if the temperature is too low, soldering results (top-side fill, bridging, etc.) may be compromised.

Dross Reduction (cont.)

- Perform wave soldering in an oxygen-free or nitrogen atmosphere: This reduces the rate of dross formation, improves the surface tension of the molten solder and reduces the risk of bridging.
- Do not keep wave machines running during idle periods: If the wave machines run "dry" – without fluxed boards passing over it – for long periods, the amount of dross will increase. Some wave machines have sensors that turn on the wave when a board approaches, and turn it off again after the board has passed through the wave. Fluxers can be activated with sensors in the same way with the added benefit of reducing air emissions. Consider precision atomizers over foam fluxers.
- Cover exposed surfaces with a "blanket": A blanket is a heat stable material that is liquid at soldering temperatures. Materials such as wax, rosin, resin, or oil should protect the molten metal from the air, except in the narrow zone of the wave. If properly chosen this material will also prevent losses of good solder with the dross.
- Avoid using excessive solder: This is often attributed to:
  - Incorrect depth of wave immersion (icicles)
  - Flux starvation
  - Marginal solderability of component or board
  - Incorrect wave exit angle or speed
  - Contaminated solder

Benefits of using an oxygen-free or nitrogen atmosphere in wave soldering:

- Reduction of dross formation
- Incidence of faulty or skipped joints drastically reduced
- Cost savings from increased efficiency
- Reduced maintenance costs
- Bridge-free soldering at finer pitches

2. Solder Recovery and Recycling

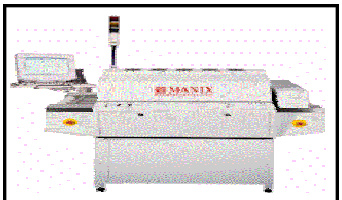
Solder recovery and recycling can reduce the amounts of waste generated and natural resources required for solder manufacture.

- If time allows, squeeze the dross through a perforated ladle to break down the crusty oxide coating in order to release some of the trapped solder back into the bath, before placing the residue into the basket.
- A solder recovery system can be installed or dross can be shipped off for recycling. Companies that ship lead dross for recycling have to get a hazardous waste recycling permit. The permit required is "BWP HW 21: Level 1, Class A Presumptive Approval Recycling Permit". The dross has to be shipped to a permitted recycler. If companies recycle lead solder on-site, the companies are required to notify DEP before beginning on-site recycling activities using the "On-Site Class A Recycling Notification Form". The recycling permit application and notification form are available on the DEP web site — http://www.mass.gov/dep/recycle/approvals/oscarpkg.pdf.
- For recycling, the Massachusetts Hazardous Waste Regulations, Section 310 CMR 30.202(5) states the following:
  - The following materials are not subject to the Hazardous Waste Regulations 310 CMR 30.200 or any other provisions of 310 CMR 30.000:
    - Whole used circuit boards being recycled provided that they are free of mercury switches, mercury relays, nickel-cadmium batteries, or lithium batteries
    - Shredded circuit boards being recycled provided that they are:
      1. Managed in containers sufficient to prevent a release to the environment prior to recovery.
      2. Free of mercury switches, mercury relays, nickel-cadmium batteries, or lithium batteries.

B. Reflow (Paste) Soldering

Many assemblers use paste to join surface mounts and hybrid devices in a process called Reflow Soldering. To minimize a loss from reflow soldering several techniques could be employed:

- Clean the stencil or screen immediately after a printing run to prevent drying in the apertures that can cause costly future defects.
- The walls and lid of partially used containers of paste should be kept clean to prevent dry particles from forming that can become lodged in the stencils or screens.



Above: Reflow Soldering Machine (Photo courtesy of Manix Manufacturing, Inc.)

Reflow (Paste) Soldering (cont.)

- Pastes removed from the stencil or screen should go to a separate, marked container, and undergo the "solderball" test before reuse.
- Store cartridges and syringes of paste vertically with the tips down to prevent air from drying the solder paste.
- Although technology allows unopened solder paste to be stored at room temperature, it is recommended to refrigerate solder paste to extend its useable life. Solder paste will warm up to room temperature naturally if removed from the refrigerator 18-24 hours before use. Heating the paste quickly will alter the physical properties and may promote defects such as slumping and bridging.
- Containers of solder paste have a "use-by" date listed on the label. Use older containers before they expire. If the shelf life of the paste is 4-6 months try to maintain only 4-6 weeks of inventory.
- Users should not tamper with solder paste in an attempt to "improve" or "adjust" the paste viscosity. Solder pastes are the result of a delicate balance between the demands of printing and of soldering.

Solder Ball Test:
6-10 mil thick solder paste patterns are deposited by stencil or screen printing on a nonmetallic substrate, such as frosted glass, or ceramic, and then reflowed, preferably using a reflow profile close to the one used in production. If the deposit is one large shiny ball, with a smooth surface, the solder paste is acceptable.— *Rudolf Strauss "SMT Soldering Handbook", Second Edition, 1998*

- The ideal relative humidity level of the room where paste is being applied is between 25% and 60%. This prevents the paste from drying out too quickly or becoming sticky and helps users to select pastes that are robust.
- For uniform thickness of the paste and for a precise printdown without smudging, the flatness of the board is very important.

C. Hand Soldering

Hand soldering is used extensively for assembly of components with small production runs, prototypes, repairs, and for hand dipping of component leads in molten solder pots. There are many small companies in Massachusetts below the 100 pound lead reporting threshold for TRI/TURA that use hand soldering in their operations. To minimize loses from hand soldering operation, some techniques could be employed:

- Use the smallest gage solder wire required for a particular job.
- Minimize use and scrap; it is important to have the proper equipment with proficiently trained operators.
- Observe proper hygiene and safety guidelines, as listed below:
  - Clean work areas daily.
  - Put particles and trimmings in a recycling or hazardous waste container.
  - Place sticky mats at exits from the work area.

Above: Example of Hand Soldering (Photo courtesy of MannCorp)

II. Industrial Hygiene and Safety

Dross contains powdered lead oxide, which is hazardous as it is absorbed easily into the digestive system and must be handled with extreme caution. Due to the toxic nature of the lead solder, it is important for workers to adopt the following safety guidelines:

- Wear heat resistant gloves as well as face, eye and respiratory protective equipment during dross removal.
- Wash hands thoroughly before smoking, eating or drinking after handling solder or dross.
- Don't smoke, eat or consume drinks on the job.
- Skim the dross gently and keep it in a covered container to prevent exposure to toxic dusts.
- The Occupational Safety & Health Administration (OSHA) regulates all occupational exposure to lead. For the limitations and monitoring requirements, see the OSHA Lead Standards for General Industry (29 CFR 1910.1025).
- Habitual nail biters should not come into contact with solder in any form unless special precautions have been taken to ensure the prevention of ingestion.

III. Hazardous Wastes

Because of the lead content in the solder layer, printed wiring board scrap could be classified as a hazardous waste. The Toxicity Characteristic Leaching Procedure (TCLP) test should be performed to determine if scrap should be disposed as hazardous waste. Companies should also determine whether or not wiping rags contaminated with lead solder are hazardous waste. This determination may be analytical or based on prior experience. If printed wiring board scraps and wiping rags are determined to be hazardous waste, they shall be disposed in accordance with all applicable requirements of the Massachusetts Hazardous Waste Regulations: 310 CMR 30.000.

IV. Wastewater

If there is an increased risk that wastewater will come into contact with lead solder, the local POTWs should be notified to determine the allowable level of lead in the wastewater discharge. Please remember that wastewater with 5 mg/L or more of lead is considered hazardous waste and must be disposed of accordingly. Wastewater with less than 5 mg/L of lead may be subject to local POTW regulations. Wastewater at risk of coming into contact with lead solder should be sampled to determine if it is within the limits allowed by the local POTW. If not, the wastewater should be treated to remove lead before being discharged or recycled or disposed of as hazardous waste.

V. Lead-Free Soldering

The Restrictions on Hazardous Substances (RoHS) Directive in Europe and similar initiatives in the United States are driving manufacturers to develop methods for producing their products with substitutes for recently banned or restricted materials. Tin-Silver-Copper alloys are leading candidates for lead-free solder. However, other solder alloys are being used for specialized applications. If a company successfully produces their product with an alternative solder, they should not assume it is safe and can be handled less carefully than the restricted material. The material may exhibit some of the same hazards as tin/lead solder. The recommendations in this document may also be valid for the alternative solder processes.

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